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Voyager Observations of Anomalous and Galactic Cosmic Rays During 1998

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Abstract

We present energy spectra of anomalous and galactic cosmic rays over a wide energy range by combining data from the Low Energy Charged Particle experiment and the Cosmic Ray experiment on the Voyager spacecraft. The data set covers all of 1998. We compare energy spectra obtained from Voyagers 1 and 2. The energy range covered contains the peak intensity in the spectra for anomalous cosmic ray hydrogen, helium, and oxygen. The spectra presented can be used to constrain models of solar modulation.

1 Introduction:

The Voyager 1 and 2 (V1 and V2) spacecraft were launched in 1977 on a mission to explore the outer planets and heliosphere and are now (17 August 1999) positioned at ~75 and ~59 AU from the Sun, respectively. (The heliospheric trajectories of the Voyager and some other spacecraft are available at http://nssdc.gsfc.nasa.gov/space/helios/heli.html). The Voyagers each carry the Low Energy Charged Particle (LECP) experiment (Krimigis et al. 1977) and the Cosmic Ray Subsystem (CRS) experiment (Stone et al. 1977). The energy ranges covered are complementary and overlapping, with the LECP instrument generally extending to lower energies and CRS extending to higher energies that include the peak intensities of the galactic cosmic rays.

In the outer heliosphere, the dominant populations of energetic particles above ~1 MeV/nuc are the anomalous and galactic cosmic rays (ACRs and GCRs, respectively).

2 Observations:

The history of ACR oxygen intensities with 7.1-17.1 MeV/nuc observed by the CRS experiment on V1 and V2 since launch are shown in Figure 1. For these particles the intensities reached a plateau indicative of solar minimum conditions in ~1993. However, at lower energies the ACR energy spectra continued to evolve as solar modulation relaxed from 1993 to 1999, as shown in Figure 2 for H and He.

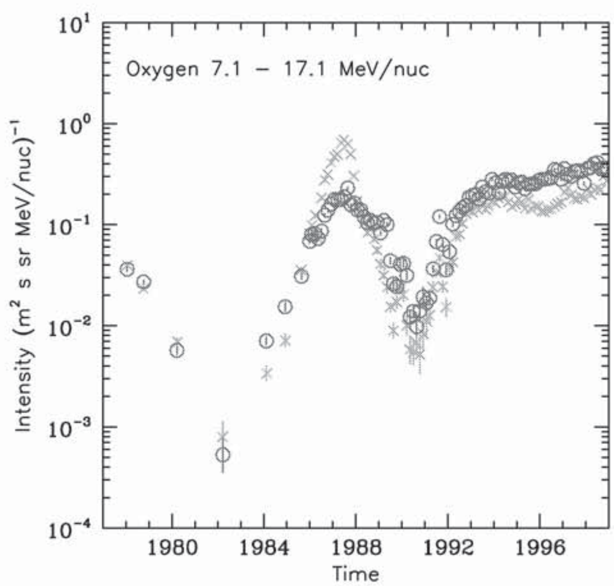

Figure 1: Intensities of 7.1-17.1 MeV/nuc ACR O observed by V1 (open circle) and V2 (cross) from 1977 to 1999. Typical particle rigidities: 1.8 to 2.9 GV.

To best represent the current solar minimum period we have chosen all of 1998 as the time period, bringing together the LECP and CRS data to present the energy spectra of ACR and GCR H, He, N, O, and Ne over as wide an energy range as possible to facilitate comparisons with model calculations. (We note that for V2 LECP data, days 120 through 154 were omitted because the instrument was in a non-standard mode during that time. A comparison of V2 CRS energy spectra for 1998 with and without those days included showed no significant differences.) This period

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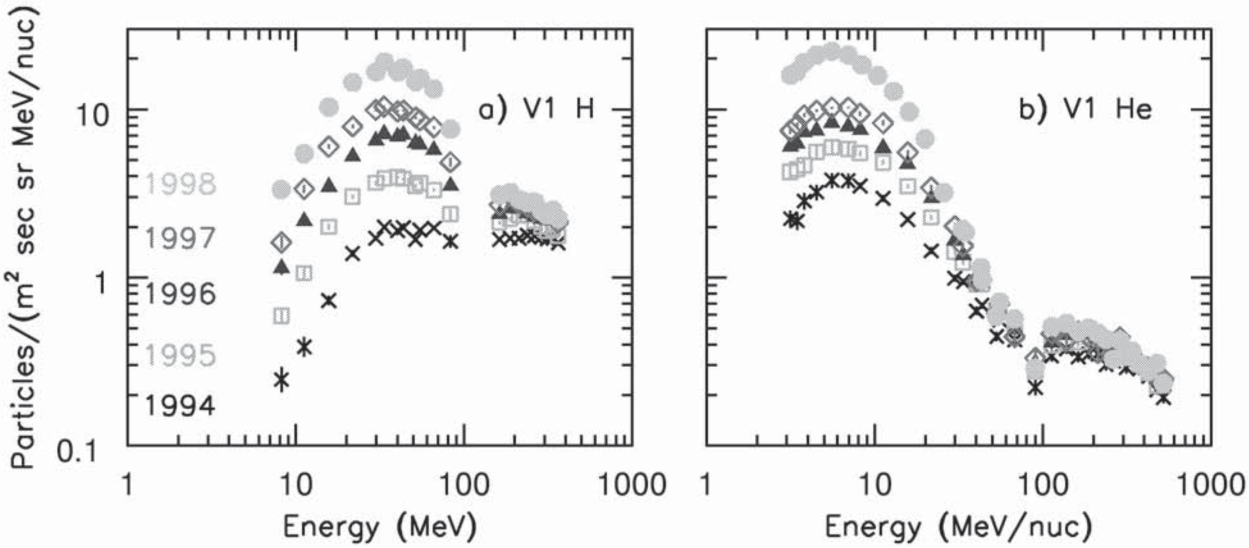

Figure 2: a) Fifty-two day averaged energy spectra of H from CRS at V1. The energy spectrum for the last 52-day period of each year is shown. b) Same as a) except for He.

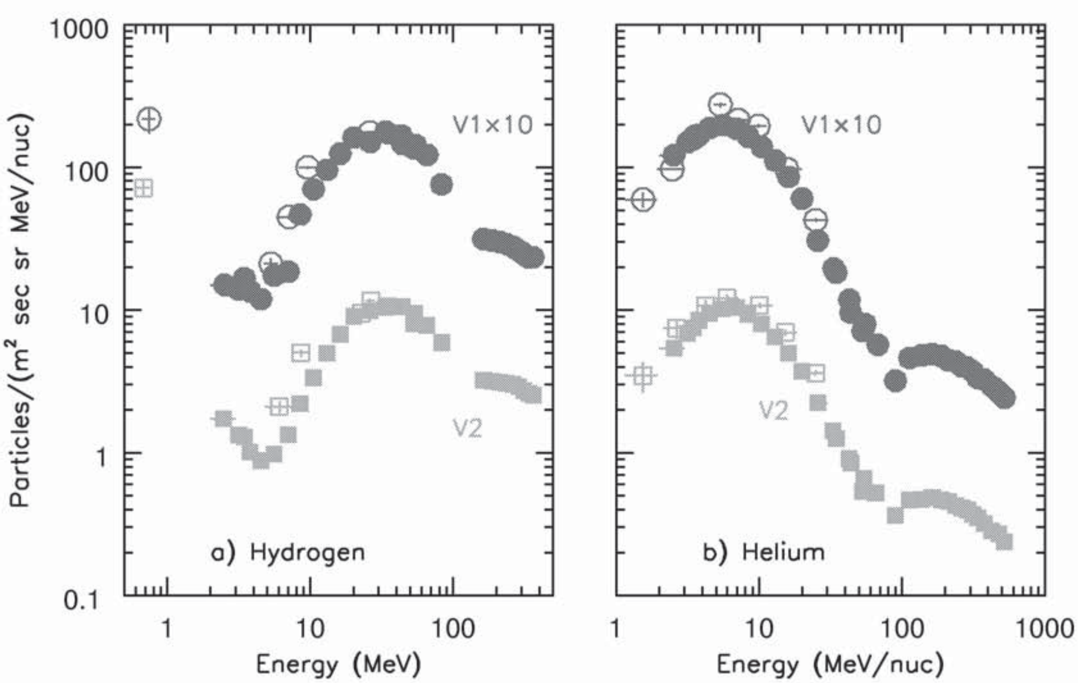

Figure 3: a) Energy spectra of H at V1 (circles) and V2 (squares) for 1998. The CRS data are shown as solid symbols, and the LECP data are shown as open symbols. b) Same as a) except for He.

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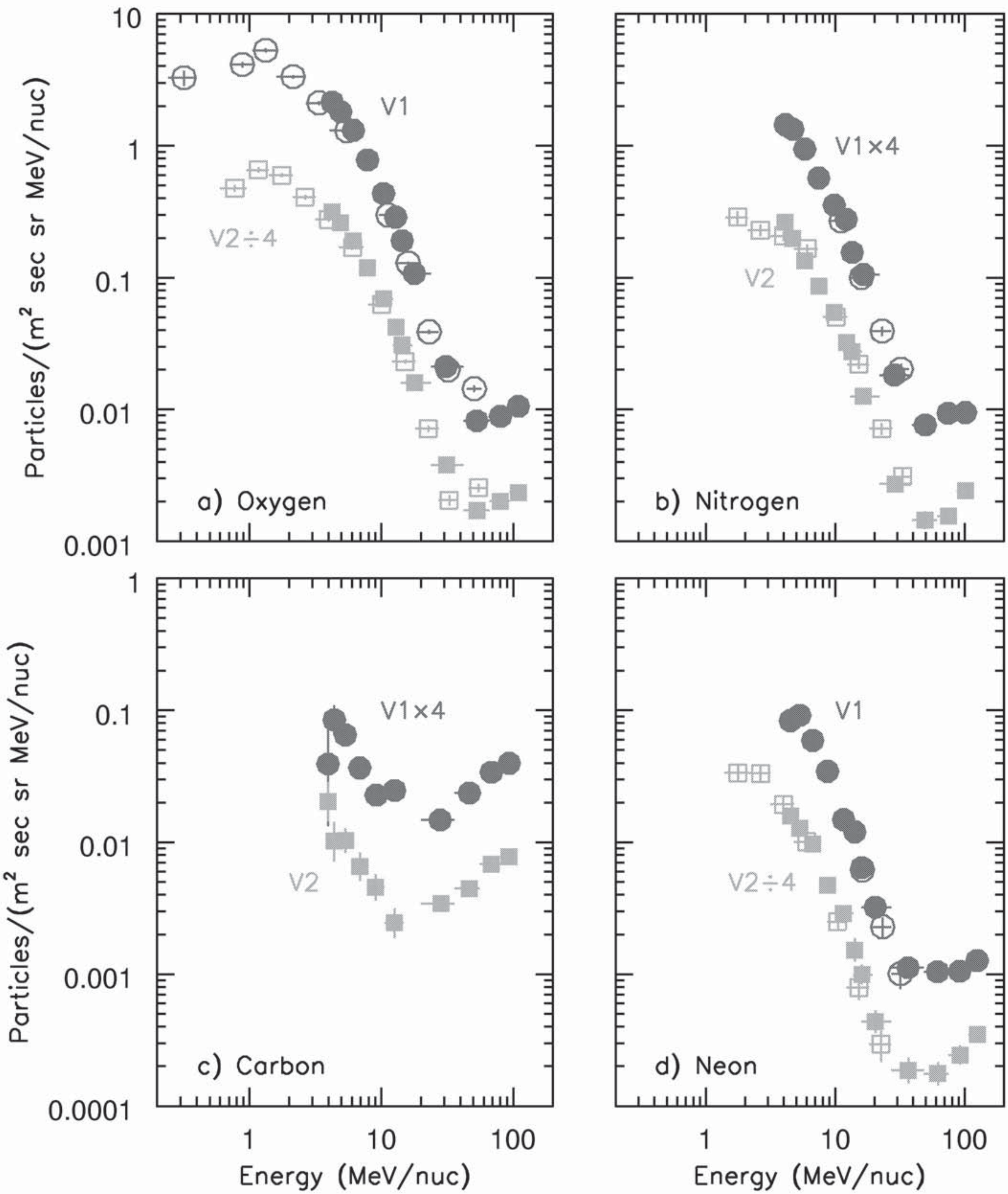

Figure 4: a) Energy spectra of O at V1 (circles) and V2 (squares) for 1998 from the CRS instrument. The CRS data are shown as solid symbols, and the LECP data are shown as open symbols. b) Same as a) except for N. c) Same as b) except for C. d) Same as c) except for Ne.

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is long enough so that the LECP data are not statistically limited and short enough so that the evolving nature of solar modulation does not distort the relative energy spectra amongst the elements. The energy spectra for H and He are shown in Figure 3 and the spectra for C, N, O, and Ne are shown in Figure 4.

3 Discussion:

As discussed by Stone et al. (1997), the modest increases in the 70 MeV/nuc (1.5 GV) He^+ flux (Figure 2) and the 7.1-17.1 MeV/nuc ($\sim$2.2 GV) O^+ flux (Figure 1) suggests a reasonably steady source flux of ACRs at the termination shock throughout the five year period leading to solar minimum. Thus, the recovery of lower energies must result from changes in the diffusion or drift processes.

The energy/nuc of the peak intensity differs for H, He, and O, occurring at lower energies for higher mass elements. Such features in the energy spectra of the ACRs, such as the energy of the peak intensity, place constraints on the models of solar modulation that attempt to describe the propagation and distribution of the particles in the heliosphere.

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